conditions where the paths of the component rays may have any length whatever. It is thus an essential extension of the same method as used for reserved spectra, heretofore, and also of the methods in which the paths are essentially small.

13. *On the Inheritance of Certain Glume Characters in the Cross Avena Fatua XA. Sativa Var. Kherson:* Frank M. Surface, Biological Laboratory, Maine Agricultural Experiment Station.

A study of inheritance of certain characters particularly directed toward revealing phenomena of linkage.

14. *A Comparison of the Rates of Regeneration from Old and from New Tissue:* Charles Zeleny, Zoological Laboratory, University of Illinois.

The data as a whole show clearly that there is no essential difference between the rate of regeneration from new cells and from old cells. The rate of regeneration seems therefore to be under central control.

15. *The Effect of Successive Removal upon the Rate of Regeneration:* Charles Zeleny, Zoological Laboratory, University of Illinois.

Apart from the slowing due to age there is no indication of the amount of new material that may be produced by regeneration. The actual limitation comes not from the using up of regenerative energy, but from changes in the non-regenerating part associated with age.

16. *The Geologic Rôle of Phosphorus:* Eliot Blackwelder, Department of Geology, University of Wisconsin.

Phosphorus appears in nature in many forms and in many situations. Its numerous transformations, however, follow an orderly sequence—in a broad way form a cycle—which is here discussed in some detail.

17. *Dominantly Fluviatile Origin under Seasonal Rainfall of the Old Red Sandstone:* Joseph Barrell, Department of Geology, Yale University.

Geologists have differed so widely in their conclusions in regard to the nature of the habitat of the early vertebrate faunas whose remains are found in the formations of the Old Red Sandstone, that the author is led to examine critically the criteria for the interpretation of the facts. He comes to the conclusion that the deposits which make up the Old Red Sandstone, although they undoubtedly contain lacustrine beds and other beds laid down in shifting, shallow and variable bodies of water, are dominantly fluviatile in origin. The Great Valley in California may therefore in the present epoch, both in physiography and in climate, be cited as a striking illustration of the nature of the Old Red Sandstone basins.

18. *The Influence of Silurian-Devonian Climates on the Rise of Air-Breathing Vertebrates:* Joseph Barrell, Department of Geology, Yale University.

The evidence for the hypothesis of the continental origin of fishes has been examined and seems to prevail over that for their marine origin. The author also believes that natural selection, although discredited as a cause determining specific variations, appears nevertheless to be a major factor in evolution.

19. *Density of Radio-Lead from pure Norwegian Cleveite:* T. W. Richards and C. Wadsworth, 3d, Wolcott Gibbs Memorial Laboratory, Harvard University.

The density of this lead is found to be 11.273, distinctly less than the density (11.289) of Australian radio-lead and still less than that (11.337) for ordinary lead, the decrease being almost exactly proportional to the decrease in atomic weight in these samples, so that the atomic volume (18.281) is constant.

20. *National Research Council.*

A preliminary report to the president of the academy by the organizing committee recently printed in full in Science.

Edwin Bidwell Wilson
Mass. Institute of Technology,
Cambridge, Mass.

SPECIAL ARTICLES

IMBIBITIONAL SWELLING OF PLANTS AND COLLOIDAL MIXTURES

The swelling of gelatine in distilled water, alkali and acid has long been used as refer-

ence phenomena in interpreting the water relations of plants especially in growth, and some conclusions founded on the assumption that growing organs, like gelatine, would show a maximum swelling in acidified solutions are shown by our work to be mistaken ones.

During the course of some comprehensive studies on growth now being carried out at the Desert Laboratory it was deemed desirable to follow the entire course of development of shoots of *Opuntia,* and to make chemical analyses at various stages. Growth depends so largely upon the capacity for absorption and retention of water that numerous measurements of the swelling capacity of developing and mature members were made.

The method consisted in cutting clean disks 12 mm. across from the flattened joints of *Opuntia.* Three of these were arranged in the bottom of a Stender dish and a triangle of thin sheet glass arranged to rest its apices on the three disks. The vertical swinging arm of an auxograph[1] was now adjusted to a shallow socket in the center of the glass triangle while the pen was set at zero on the recording sheet. Water or a solution being poured into the dish, the course of the swelling was traced.

That the amount of imbibition depended mainly upon the presence of certain recognizable substances and not upon properties of the disks as masses of living material was demonstrated by the fact that dried disks gave proportionate differences equivalent to those of living material.

The average thickness of disks varied from 4 or 5 mm. in the case of young joints to 18 or 20 mm. in mature ones. The apical parts of joints showed greater capacity for absorption than the basal ones in the proportion of 21 or 22 to 16 or 17 per cent. Comparative tests were finally based on disks taken from apical regions. The capacity for absorbing water was seen to increase up to maturity (about 1 year old) then to decrease as illustrated by the following set of tests with *Opuntia blakeana* made May 17–29, 1916.

Opuntia blakeana	Young	Mature	Old
Swelling (distilled water) ..	24.3%	50%	41.3%

The amount of imbibition does not appear as a continuous function of any one substance or group of substances, the presence and amount of which were estimated. This would harmonize with the results of swelling mixtures of gelatine and agar described below. The phenomena of proportionate swelling of gelatine in water, acids, alkalies and salt solutions have been mistakenly used hitherto in attempts at explanation of the mechanism of growth. It has been demonstrated by repeated tests that the tracts of growing cells studied, as well as maturing or mature tissues, do not swell more in acid than in distilled water or alkali, as will be illustrated by the following results taken at random from numerous records obtained at Tucson.

SWELLING OF DISKS OF OPUNTIA

	Dist. Water	Sodium Hydrate (Hundredth Normal)	Hydrochloric Acid (Hundreth Normal)
Young.....	**23.6%**	22.9%	16.4%
Mature.....	40%	52.1%	**36.6%**

It is conclusively established that both young and old tissues take up more water when neutral or alkaline. Acidity therefore in addition to retarding enzymatic action presumably including respiration would operate to lessen growth by its effects in decreasing imbibition by plant tissues.

It being demonstrated that growing masses of embryonic cells in plants and tracts of mature tissue show their greatest capacity for the imbibition of water not in acidified but in alkaline solutions, it was sought to find what substance or mixture of substances would behave in a similar manner. The first inquiry was made with agar which is composed of pentoses presumably having some qualities identical with those of the mucilages of the plant. Dried cylinders and sheets of this material were first subjected to the tests, being placed under the auxograph after the manner in which disks of living material were treated as described in a

[1] See MacDougal, D. T., "Mechanism and Conditions of Growth," *Mem. N. Y. Bot. Garden,* 6: p. 14, 1916.

previous paragraph. The results compared with the swelling of gelatine were as follows:

	Sodium Hydrate (Hundredth Normal)	Hydrochloric Acid (Hundredth Normal)	Water
Swelling of agar.....	124%	113%	197%
Swelling of gelatine..	250%	382%	83%

As the plant did not show water relations which might be interpreted as a mechanical resultant of the separate action of gelatine or agar it was next proposed to test the reactions of a mixture in which these substances would be blended, which was done in July, 1916. The first test mass was one consisting of about equal parts of agar and gelatine, though the quantities were not weighed. Both were soaked and melted separately and the gelatine was poured into the hot agar which was kept at a temperature of about 90° C. for a half hour. The mass was then poured on to a glass slab for cooling. Two days later it was stripped off as a fairly clear and transparent sheet slightly clouded, the average thickness of which was 0.2 mm. Strips about 5 × 7 mm. were placed under the apices of sheet glass triangles in glass dishes after the manner in which plant sections had been tested, and auxographs were arranged to record the action of acids, alkalies and distilled water. The first trial made on July 21 gave the following final relative size of the strips as compared with the original: distilled water 850 per cent.; nitric acid (hundredth normal), 725 per cent.; hydrochloric acid (hundredth normal), 750 per cent.; sodium hydrate (hundredth normal), 950 per cent. No record of the temperature of the room was kept. A second test on the following day at temperatures of 61°–65° F. gave the following: distilled water, 675 per cent.; hydrochloric acid, 625 per cent.; nitric acid, 687.5 per cent.; sodium hydrate, 750 per cent. These results were taken to be of such importance that a series of mixtures of agar with 20, 50 and 80, 95 and 99 per cent. of gelatine by dry weight were made up. The mixtures were poured into moulds on glass plates and dried sheets from 0.1 mm. to 0.6 mm. in thickness were obtained. The measurements given below include the results of tests under varied conditions not only of thickness of the samples, but also of temperature, length of period of swelling, tension of instruments, etc. Each set of three measurements of the swelling in the three liquids is therefore to be considered separately, and is not to be compared with one above or below, either as to amplitude or relative swelling, as the experiments were varied in many ways. For the sake of completeness some results with agar and with gelatine alone are included.

Gelatine

Sodium Hydrate (Hundredth Normal)	Hydrochloric Acid (Hundreth Normal)	Distilled Water
280%	560%	250%
125	283	125
	Gelatine 100—Agar 1	
750	1,100	520
	Gelatine 100—Agar 5	
667	767	325
704	933	333
	Gelatine 80—Agar 20	
800	700	425
875	775	—
600	900	—
850	650	558
600	600	275
900	1,000	600
700	900	300
	Gelatine 50—Agar 50	
788	788	692
500	333	1,133
600	350	525
675	225	—
400	350	500
600	200	700
450	300	875
633	367	1,167
	Gelatine 20—Agar 80	
600	400	1,150
600	600	1,450
600	700	1,200
450	700	1,150
433	533	767
600	500	1,200
	Agar	
400	650	775
525	800	1,100

The outstanding fact that a mixture consisting mostly of gelatine, to which a small proportion of agar has been added, shows its greatest swelling in alkaline solutions is the most important feature of these results. The mixture in question is available as a physical analogue which has already been found useful in the study of growth and swelling of plants.

The data of the table indicate that as the percentage of agar in the gelatine is increased the mixture swells more in distilled water and less in acid or alkali, thus approaching the behavior of pure agar. Concerning the relative effects of acid and alkali, assured conclusions are not now possible but the data suggest that acid tends to increase imbibition at the ends of the series, that is as pure agar and pure gelatine are approached, while alkali tends to increase it in the middle mixtures containing the two colloids in more nearly equal proportions.

D. T. MACDOUGAL

DESERT LABORATORY,
TUCSON, ARIZONA

THE THEORY OF AUTONOMOUS FOLDING IN EMBRYOGENESIS[1]

THE experiments of Roux,[2] carried out on the embryonic chick, prove conclusively that the folding of a neural plate into a neural tube is not dependent, as His[3] had supposed, on the mechanical effect of one tissue upon another, but is autonomous. Self-differentiation in this instance is identical with self-folding. The question therefore arises: How can the neural plate fold itself?

Our reply must necessarily bear on all cases of autonomous folding, and reciprocally any one of them might serve as the basis for this analysis. The nervous system, however, is by far the largest, most easily studied, and, in addition, the most familiar of all the embryonic tissues in which self-folding occurs. Moreover, in its simpler forms, it indicates so clearly the direction in which an explanation of its autonomous transformations is to be sought, that for the present it seems best to limit the discussion to what may be justified as a type case.

For our immediate purposes, the neural plate of *Cryptobranchus allegheniensis* is especially suitable. Not only is it unusually large, as neural plates go, but wherever cell-boundaries are distinct, it is, without question, unicellular in thickness. The first problem to be solved is the rôle of cell-multiplication.

In a neural plate in which the cells are irregular in position and dovetailed into one another as they are in crowded columnar epithelia, inequalities in the rate of division and protoplasmic synthesis at or near the two surfaces might lead to folding, but in the *Cryptobranchus* embryo, in which the plate is partly syncytial and in which the visible cell-walls are continuous from one surface to the other, and remain so during the entire period of folding, it is difficult to conceive how cell-multiplication could result in anything except uniform enlargement. The exclusion of this factor from participation in the process of involution, however, does not depend on mere argumentation, for comparison of the number of nuclei in comparable regions of the flat, half-folded, and completely folded plate, shows that the number of cells per section actually does not increase[4] (Table I.). Indeed in less simple material, such as the neural plate of the mammal, in which the number of cells does increase during folding, the restriction of the mitoses to the concave surface must, if effective at all, exert a force opposed to the forces that bring about the curvature. In this instance,

TABLE I

Number of Nuclei in Comparable Sections

Stage I, Flat	Stage II, Half-folded	Stage III, Folded
63	56	55
53	64	60
58	50	73
69	56	47
72	50	69
58	82	59
59	70	64
58	74	51
58	58	52
68	51	55
Ave. 62	61	59

[1] Read at the joint meeting of the American Society of Zoologists and Section F of the American Association for the Advancement of Science, in Columbus, December, 1915.

[2] "Die Entwicklungsmechanik," W. Engelmann, Heft 1, Leipzig, 1905.

[3] "Unsere Körperform, und das Physiologische Problem Ihrer Entstehung," F. C. W. Vogel, Leipzig, 1874.

[4] For the validity of these comparisons see Glaser, *Anatomical Record*, Vol. 8, pp. 528–530.